Project to Design and Build a Marble Lifting Model Using 4-Bar Linkages to Raise the Marbles

By: Dale C. Maley

Background

I have designed and built large marble lifting models using these methods of lifting the marbles:

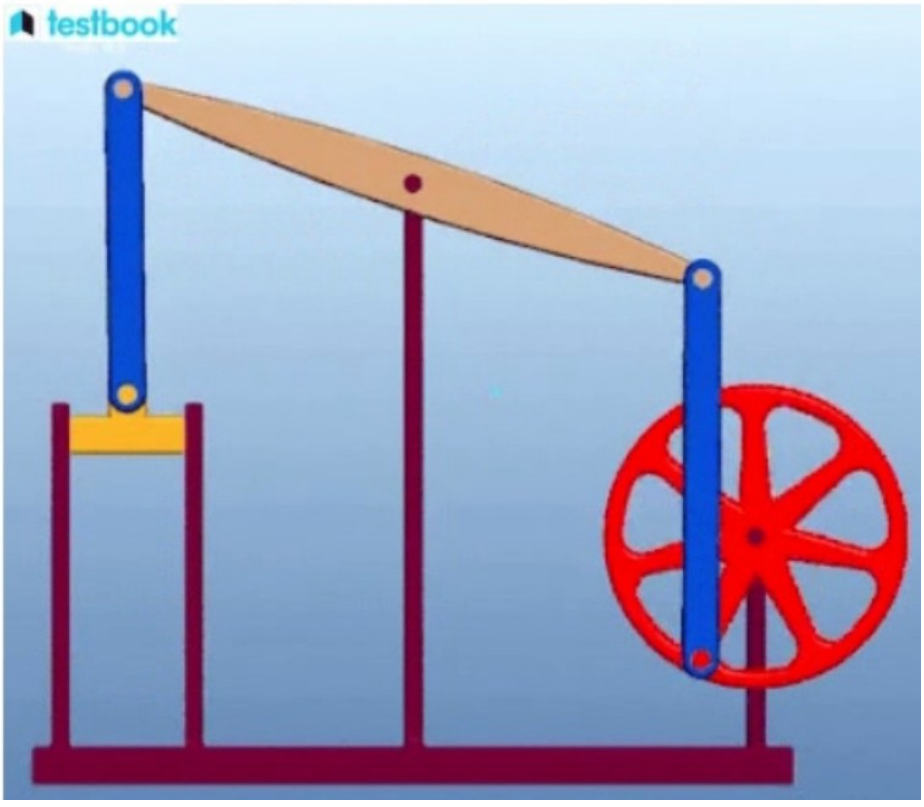
1. Grain Elevator Concept – Marble carriers or buckets are attached to a wood chain to raise the marbles.

2. Piston Pump – Like a 1 cylinder engine, marbles are lifted 1 at a time each hand-crank revolution

3. Two 4-bar linkages transfer the marbles 1 at a time between each other and then dump in a return chute

4. Cams and lifters are used to raise the marbles.

I saw a computer simulation of a 4-bar linkage used on steam engines and crude oil pumps.



So, instead of a cylinder moving up and down, what if it raised a 1” marble up instead?

I could have 2 mechanisms where first raises it up, releases to 2nd mechanism, and it takes it the rest of the way up maybe.

Is Math Already Done for this mechanism?

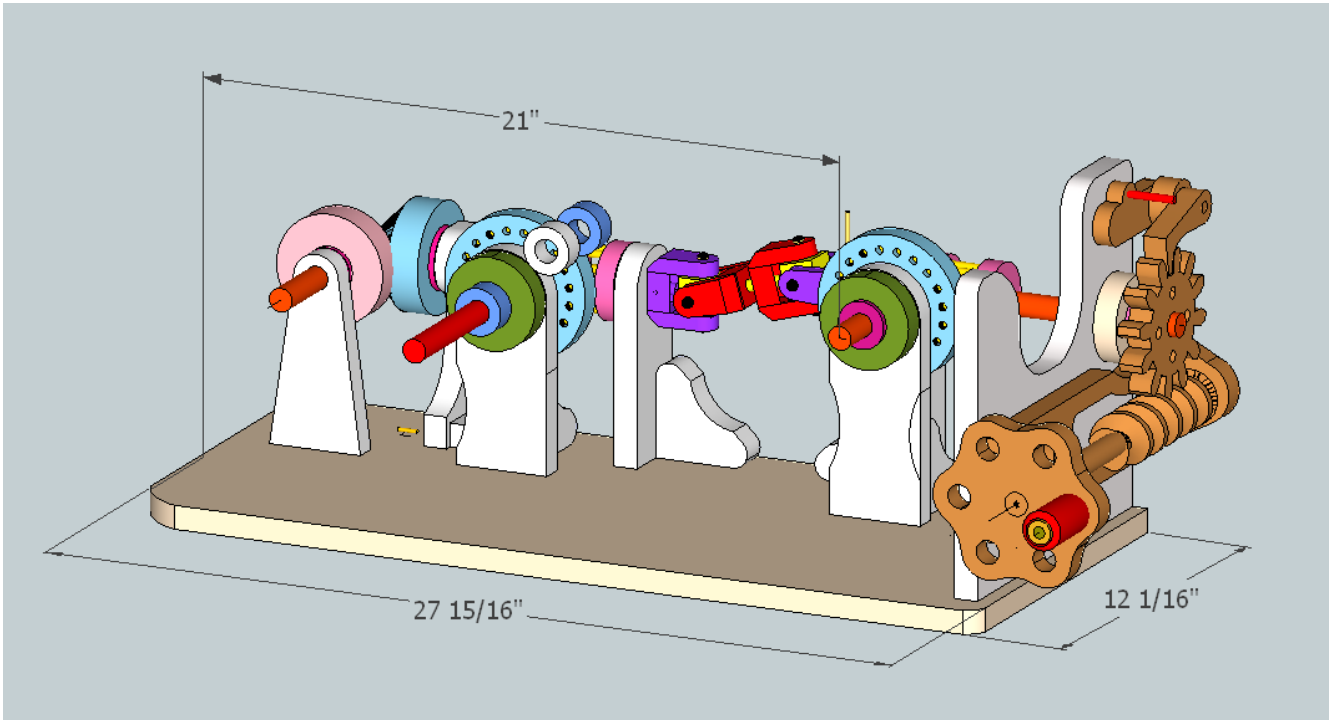
I checked the Internet, found no online calculators available. Will have to a combination of Linkage. Exe, Sketchup, and an Excel spreadsheet to model it.

Limitations

I like my big models to fit on a base plate that is about 12 inches deep, about 24” inches long, and the mechanism can extend maybe 24” high.

I will probably use a worm gear to reduce the hand-cranked speed of 100 RPM max by kids for short time periods, down to something below 10 RPM.

I took my last big model, kept the base plate, and the worm gear assembly, to get an idea of how much space I have to work with on the 4-bar linkage mechanisms.



So, the 1st 4-bar linkage will be driven by the LH peg gear. So my packaging size limitations for the 4 bar linkages is:

Crank Radius max	5”	To keep from hitting the RH vertical wall that is about 5.75 away from the center of the peg gear drive. I could move the peg gear drive to the left to get more crank radius if need be.
Linkage Length Max	10”	just a guess
Beam Max Length	18”	I have about 20” available to the left of the drive. ½ the beam or rocker arm length will go to the pivot. Use 9” as max of ½ of the rocker arm length

Linkage. Exe

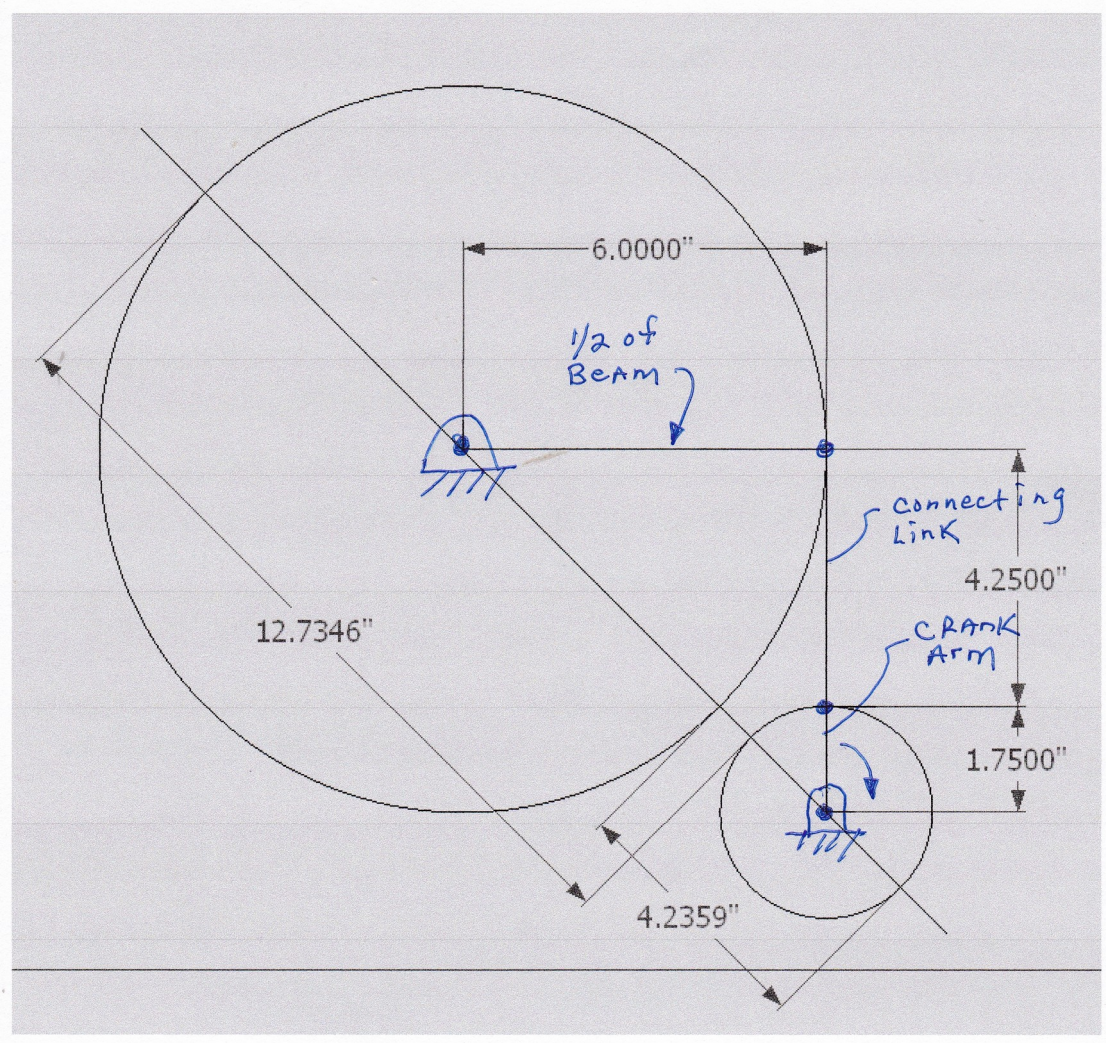
I went into this program and played around until I got a configuration that would run and not crash the program (it checks for interference, which is good).

Crank Arm Radius	Link Length from crank arm to beam	1/2 the Beam length	X for crank arm up	Y for crank arm up	X for top of Link from crank arm to beam	Y for top of Link from crank arm to beam	Length from beam pivot to crank center	Max Link length needed when crank away from beam pivot	Clearance for connecting link when crank away from beam pivot	Linkage works	Beam Rotation, slightly less than this (Degrees)	Piston travel
1.75	4.25	6.00	0.00	1.75	0.00	6.00	8.49	4.24	**-0.01**	yes	45.0	

Turns out there are 3 key inputs to the design of the rocking beam:

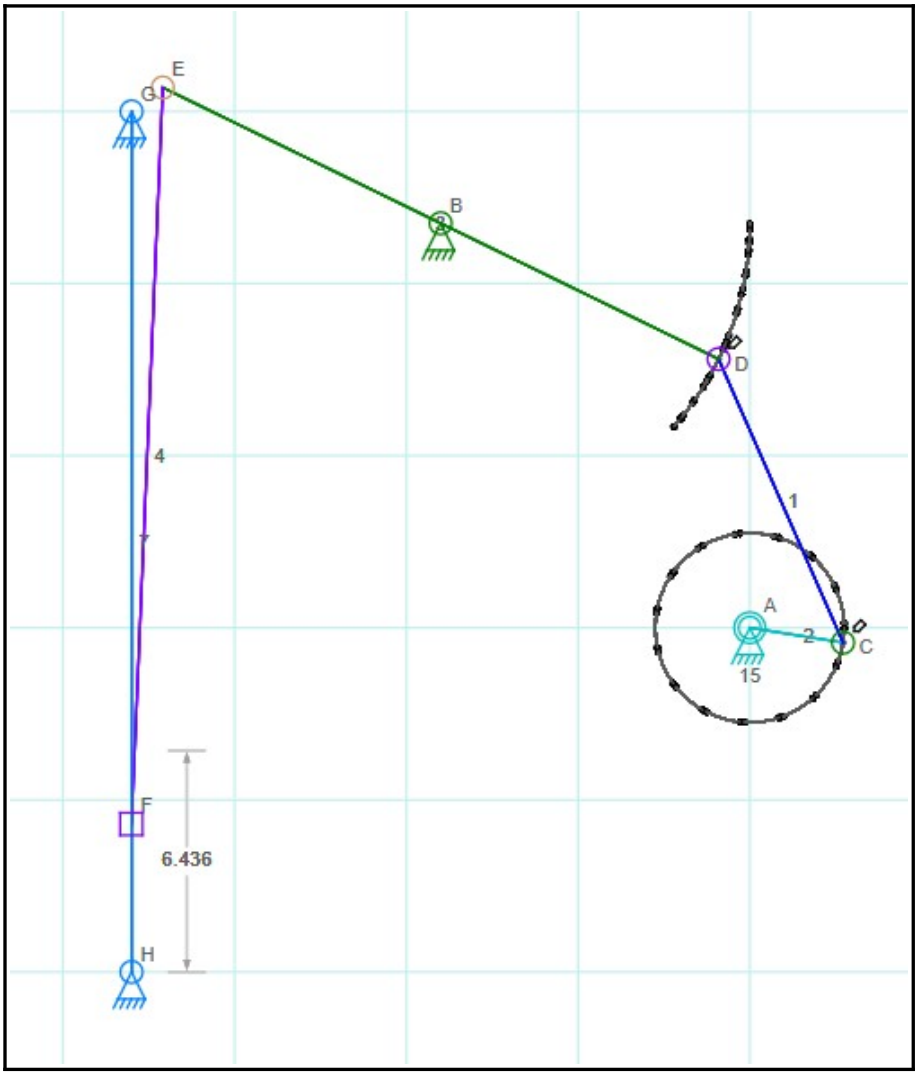
1. Radius of the crank arm
2. Length of connecting link between the crank end and the beam end
3. Length of rocking beam. I’m using ½ of this total length because it will pivot in the center.

The first configuration I found that would run on the Linkage program was 1.75” crank arm radius, 4.25” connector link length, and ½ the beam length of 6 inches.



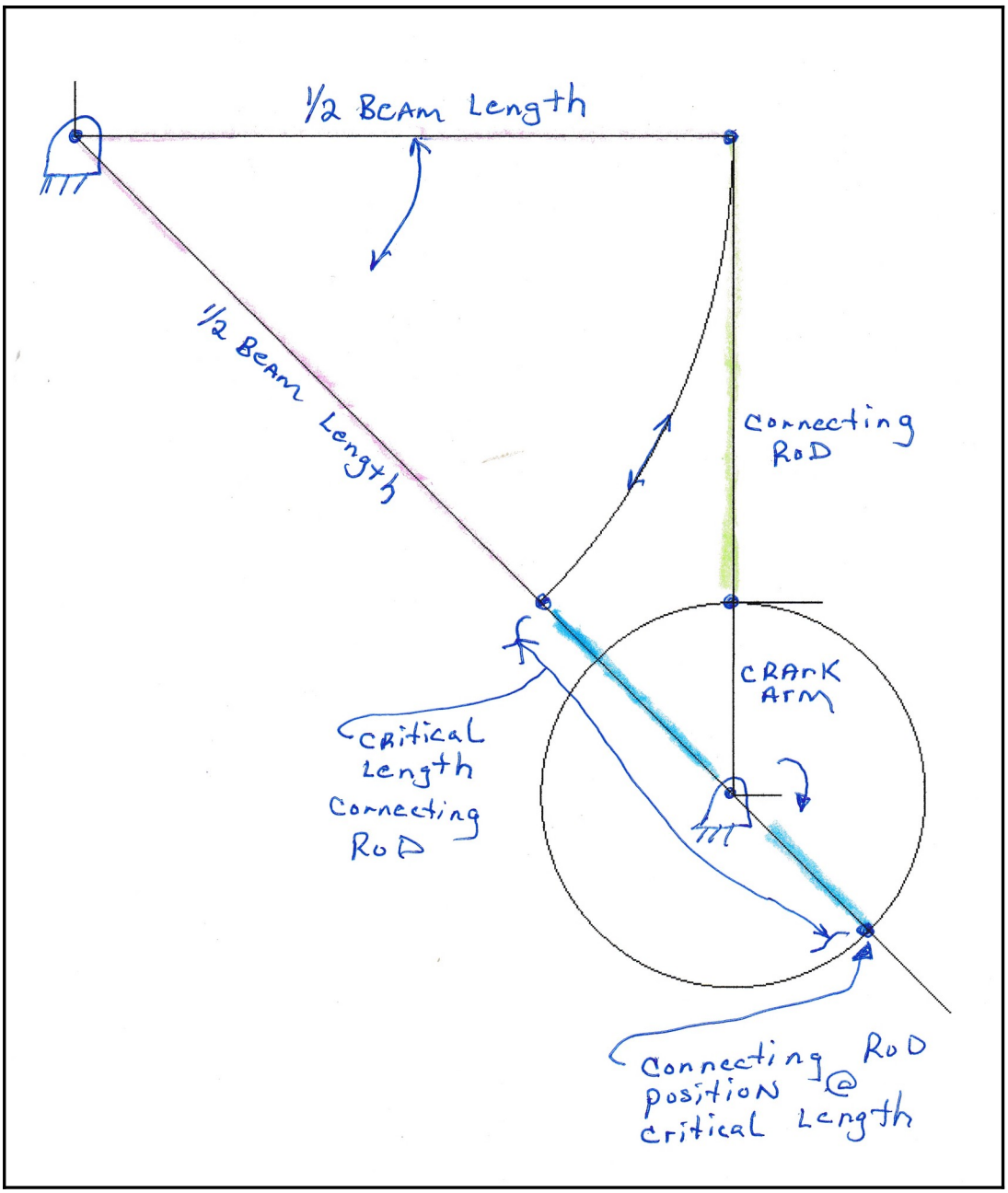
Missed an Item

When I first analyzed this mechanism, I assumed (that deadly word), that the crank arm rotated 360 degrees (which is does) and also the ½ of the rocking beam also rotates 360 degrees. It does not rotate 360 degrees !! It only rotates around 45 degrees, not 360.



This is a screen shot from the Linkage.exe program. It shows that the rocker arm only rotates about 45 degrees.

How to Construct the Excel Spreadsheet



The 4-bar linkage crashes if the geometry between the 3 inputs is not correct. One can determine the critical point by calculating the max distance of the connecting rod (shown in blue) as compared to the actual connecting rod length.

Crank Arm Radius	Link Length from crank arm to beam	1/2 the Beam length	X for crank arm up	Y for crank arm up	X for top of Link from crank arm to beam	Y for top of Link from crank arm to beam	Length from beam pivot to crank center	Max Link length needed when crank away from beam pivot	Clearance for connecting link when crank away from beam pivot	Linkage program works	Beam Rotation, slightly less than this (Degrees)	Piston travel
1.75	4.25	6.00	0.00	1.75	0.00	6.00	8.49	4.24	**-0.01**	yes	45.0	
1.75	4.00	6.00	0.00	1.75	0.00	5.75	8.31	4.06	0.06	no		
1.75	4.50	6.00	0.00	1.75	0.00	6.25	8.66	4.41	**-0.09**	yes	46.2	
2.75	9.00	9.00	0.00	2.75	0.00	11.75	14.80	8.55	**-0.45**	yes	52.6	6.4
3.00	9.00	10.00	0.00	3.00	0.00	12.00	15.62	8.62	**-0.38**		50.2	

Assuming a max length of ½ of the beam of 9”, it appears the most lift for the marbles (or max angle the beam rotates) occurs with the 3 inputs of 2.75, 9, and 9 inches. The angle of rotation is about 52.6 degrees (it is actually a little less) and from the Linkage.exemodel, should give a marble lift of 6.4 inches per 4-bar linkage mechanism.

I played around with the 3 inputs using the spreadsheet, and this is the best I can do.

Small model

What if I wanted to build a small model of the 4-bar linkage?

Key inputs would be 1.75, 4.25, and 6 inches. What piston travel does Linkage. Exe program give?

4.28” of piston travel from Linkage program.

I might want to build a smaller model just to demonstrate the mechanism. There is only about 50 degrees or angular rotation on the beam, so maybe not very exciting to watch, and therefore not worth doing a big model with 2 mechanisms?

Use Offset on upper linkage

Looks like if I use an offset from LH side of rocker to vertical slide, I can get more travel. The offset does not help on lower level 4-bar linkage.

Key 3 Parameters I chose to Use on the Model

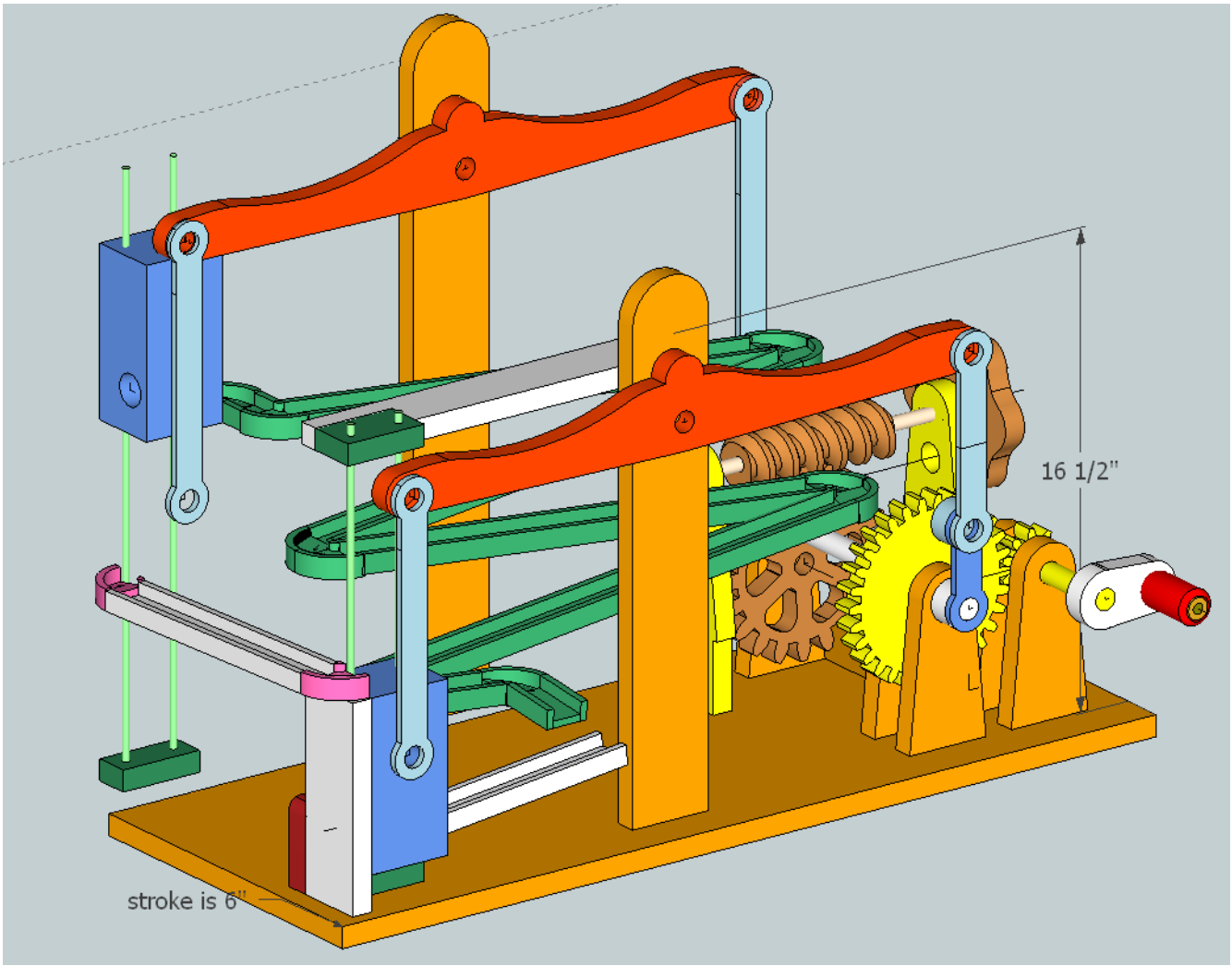
Crank Arm Length	2.75
Connecting Arm Length	6.0
1/2 of Rocking Beam Length	11.0

Will Marble Carrier design on the Pistons be the biggest design challenge?

On the Elevator + Chain big hand-cranked model, designing the marble carriers was the biggest design challenge.

It is possible the carrier design on this model may turn out to be the biggest challenge also?

First Sketchup Design Concept



Hand-Crank Drive System

I will probably build up part of the model, then hand crank it and time it, to see the max speed the model will run at.....then build a worm gear drive to get that speed from a 100 RPM max input

Big OOOPS

As I was developing the design in Sketchup, I ran into 2 obstacles:

1. I made the piston blocks about 3" wide. This means that 3 marbles will load and I want just one. I probably need to reduce the width down around 1" to match the marble diameter and get 1 to load at a time.

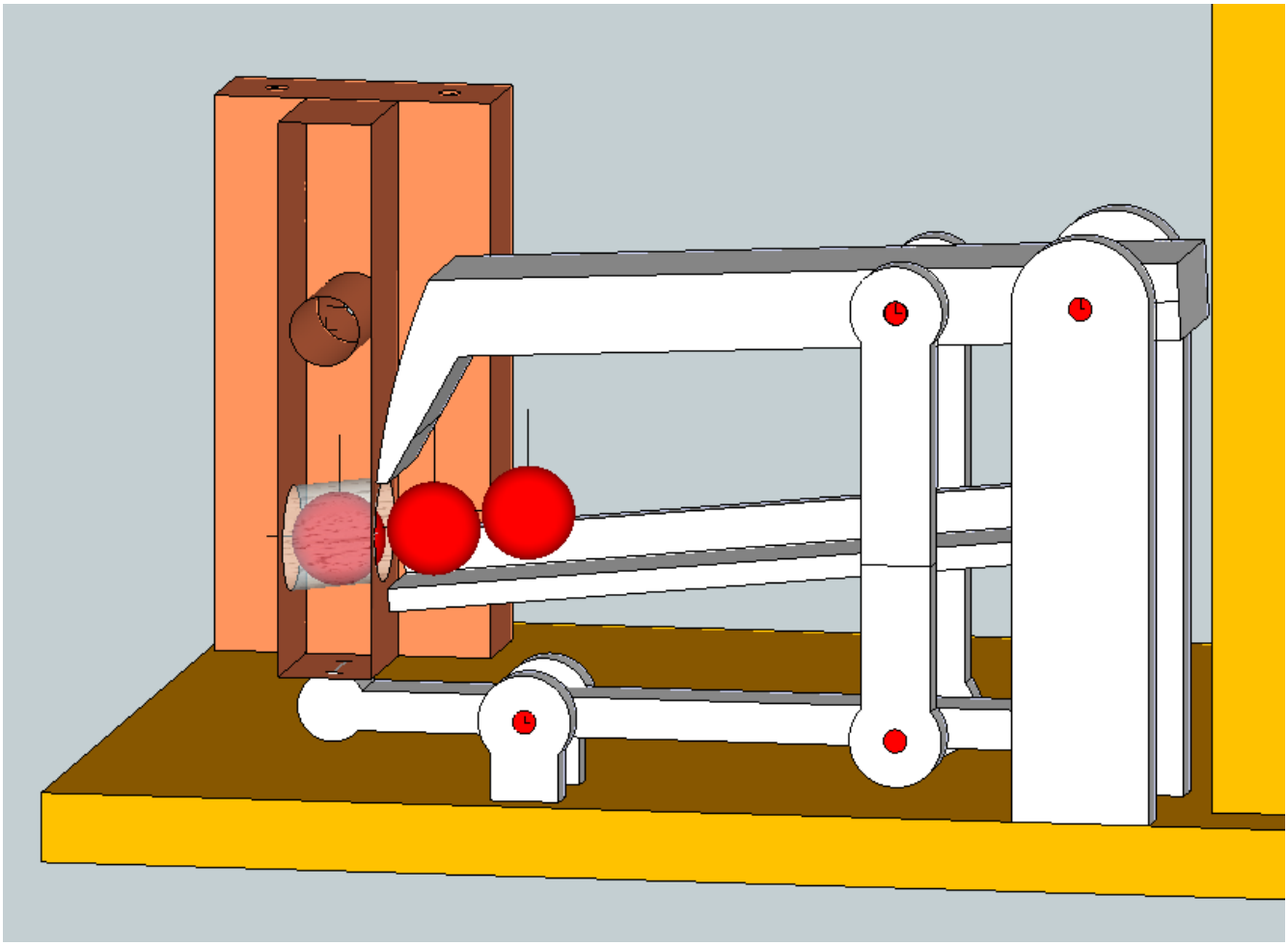
2. Once marble loads into bottom piston and the piston starts to raise up, what will keep the marbles that are waiting to load from simply traveling left and falling off the chute?

   I could make the piston 6" longer on the bottom, then piston holds the waiting marbles in place. Problem is, this raises my marble model over-all height by 6".....and I don't want the model to be that high!

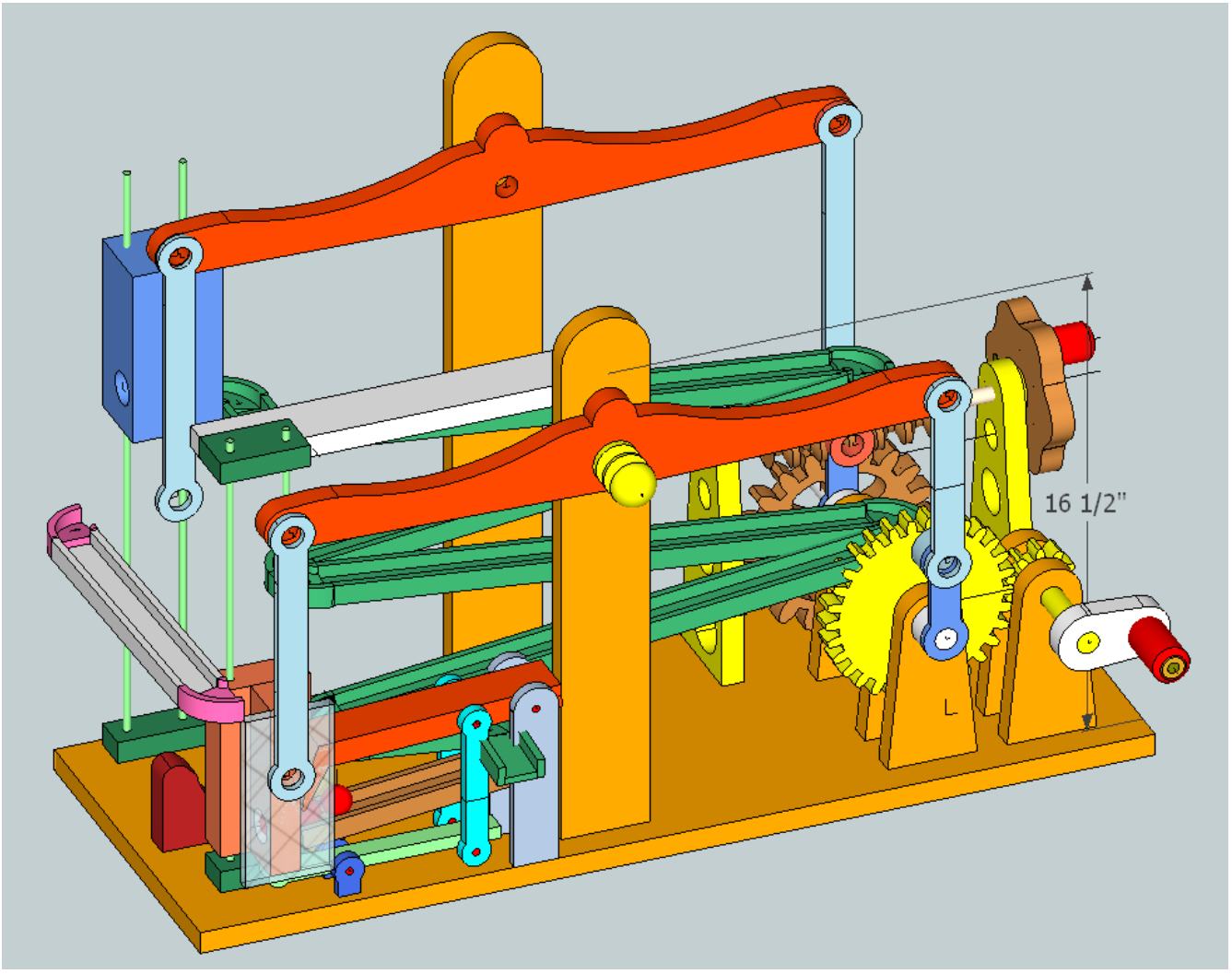
   Maybe develop some time of ratcheting mechanism to index each time the piston comes down?

   I can make the upper piston 6" longer on 1 side if I need to.

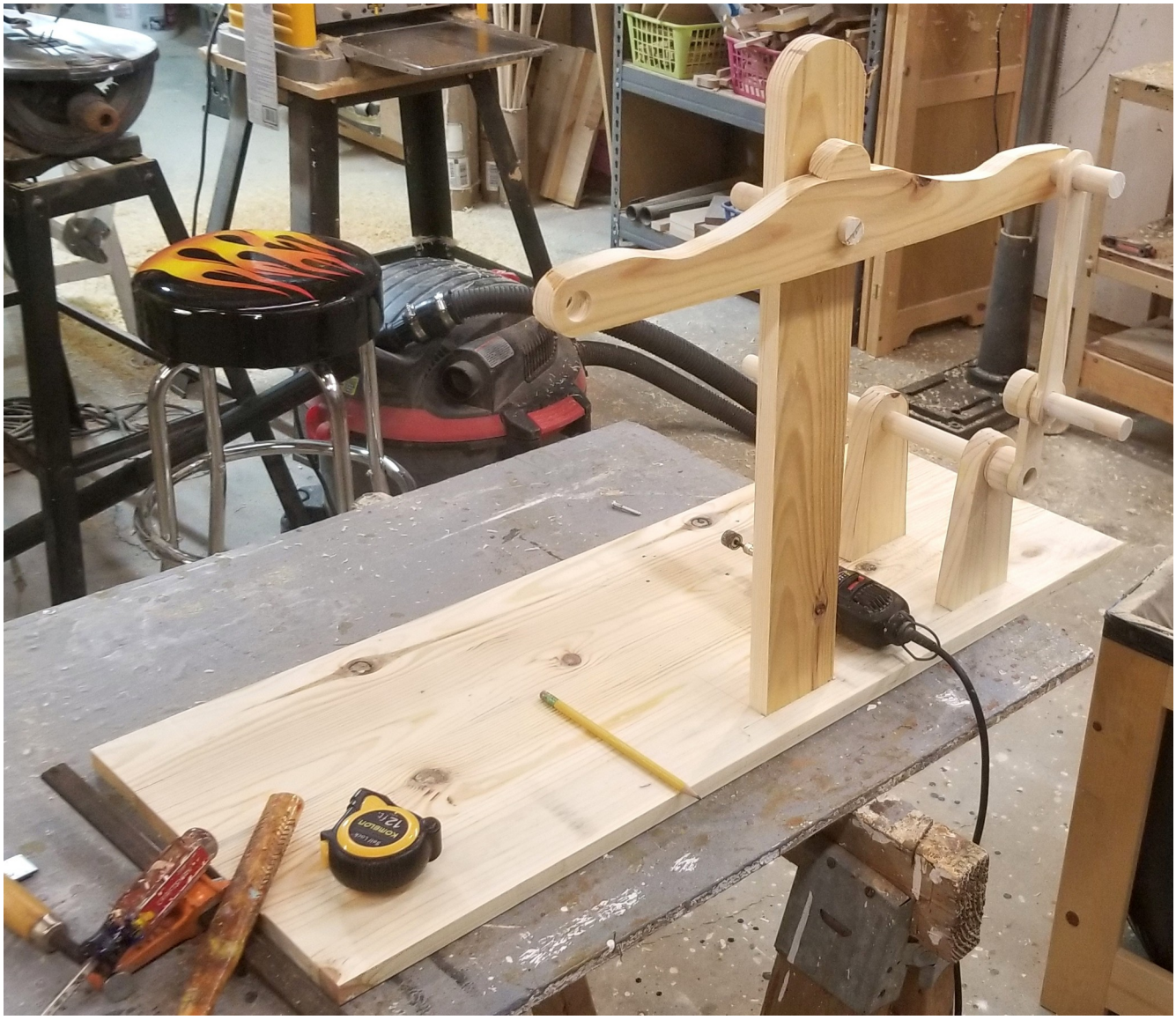
Updated Design



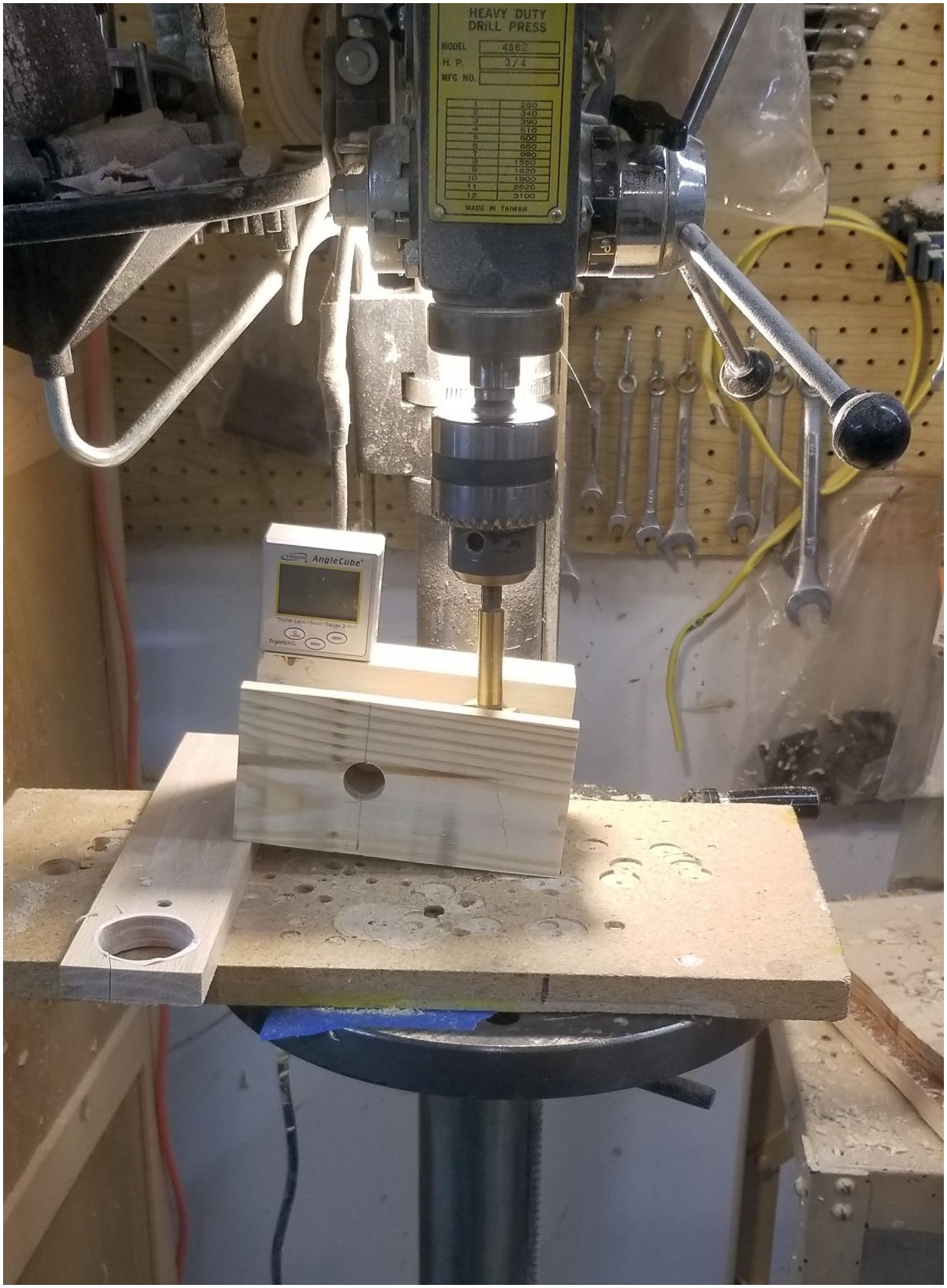
The vertical board on the LH side of the piston is not shown, but can be easily added. I may need to add weight upon the upper link so it wants to go down, when the piston goes up.


16 1/2"
L

Starting the Actual Build on 12-30-2024



Making the lower Piston with marble hole at 6 degrees


HEAVY DUTY
DRILL PRESS
MODEL 4562
H. P. 3/4
MFG NO.
1 260
2 340
3 390
4 510
5 600
6 650
7 990
8 1550
9 1620
10 1900
11 2620
12 3100
MADE IN TAIWAN
AngleCube
TrigleMAG

First Problems during Build

The horizontal arm that attaches to the front vertical arm, had an interference with the ¾" dowel that runs the rocker. I had to design an offset bracket to keep it away from the back of the dowel.

On the piston, I drilled first with an F drill, not enough clearance for the ¼" birch 2 dowels so drilled larger until I got a good sliding fit. Bit was hair smaller than 5/16" bit.

I made the center piston piece 1" thick to match the 1" marble diameter because I want the 2nd marble to load to stick out from the piston so my indexing arm could get in there. 1st marble went deeper than I expected, making it difficult for indexing arm to work. More development required on this tomorrow.

Marble Lower Loader design development

Because the first marble goes into far into the piston, my indexing arm does not come down in the right place.

-Added a piece of tapered shim to the LH side of the piston. This reduces the clearance between there vertical board and the moving piston, which decreased the amount the marble goes down into the angled hole. Taper probably helps to prevent jams between piston and the shim piece.

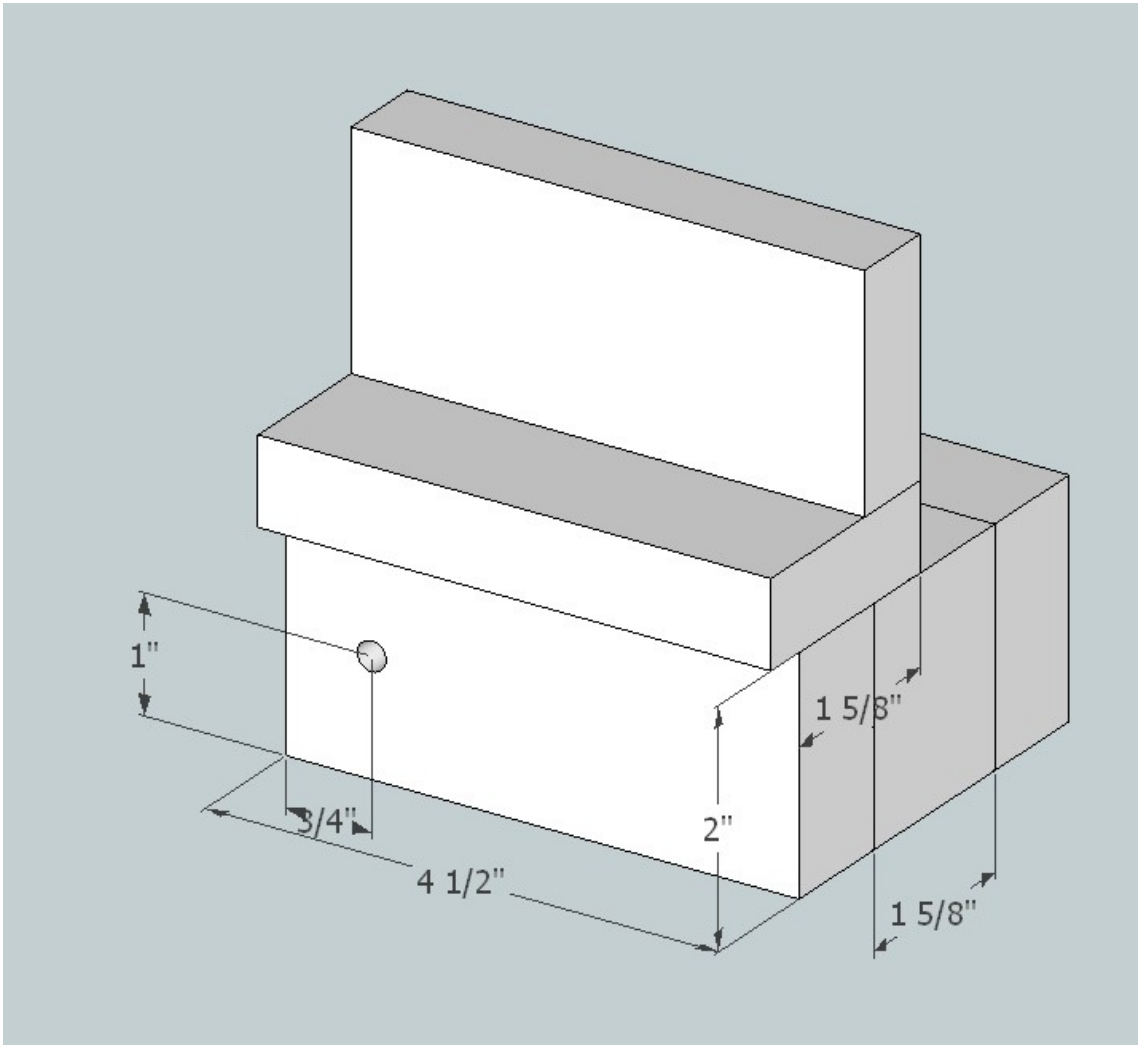
-Used table saw to take out about ¼" on the right hand side of the piston.
Hole for linkage arm dowel is slightly cut out, but I think that is OK

-Got lower chute installed at a 5 or 6 degree angle. Need it to check the whole operation

-My Sketchup is not right after I took ¼" thickness from the piston, so use trial & error to find right spot for the ¼" dowel pivot point on the vertical column.

-One surprise finding, it takes a little time for the marble to travel from the RH side of the indexing arm down into the piston angled hole. If you crank the mechanism too fast, then marble is not released, or jams.d
-this could set the max speed the model will run at??
-to get the worm gear reduction ratio

-If index arm goes up a little higher, does this buy a little time for the marble to go down into the chute, and therefore you can crank the mechanism faster?
-any way I can make a temporary movable piece with the ¼" dowels, so I can do trial & error on best location for the index arm pivot point??



RPM Testing

I tried 1 sec per rev, and the model worked OK…....this would be 60 RPM !! If you go faster, then problems start with loading.

100 max RPM /60 = 1.6 Ratio so 2:1 spur gear reduction would work on this model…….I don't need to make a worm gear.

Go Back to Sketchup Layout for indexing arm.

If I move the pivot point for the arm down to a horizontal line from the tip of the arm, then the arm swings in an arc and the distance between the tip and the piston never changes. This should let me get the tip of the arm closer to the piston, which should help loading.

Make 2 new Links and 1 new indexer arm

new links have 4.75 inch centers on pivot holes.

Results of Design Change

Made new indexer arm and 2 new links, ended up using new arm and 2 old links through experiments.

How I timed mechanism:

-loaded 6 marbles into the chute
-Started stopwatch app on cell phone
-cranked fairly slowly until 6 marbles fell into a bowl, took 15 sec for 6 marbles

6 revs/15 sec x 60 sec/min = 24 RPM

100 max kid's RPM / 24 RPM = 4.2 Reduction Ratio

Can I Model the load mechanism in Linkage. Exe?

Yes, it has a linear actuator. I made several models in Linkage.

Thoughts

I chose to trigger index arm from bottom of piston, versus say a pin on the side of the piston.

So, arm does not start to go up until the last ¼" of travel of the piston…….so I am using only a ¼" of piston travel to open the index arm by more than 1", maybe at 1.5".

Result is not much time for arm to raise and then the marble to travel down the chute into the piston, which reduces the marble loading rate.

So, I have about 1" from bottom of marble hole in piston to bottom of the piston. If I could get the arm to raise say when the bottom of the piston travels down and has 1" to go to the bottom, that leaves more time for the marble to travel down the chute.

But a pin on the side of the piston continues to move down until the piston reaches the bottom….this could make the arm open too much??

Video

I used and awl to simulate the ¼" dowel pivot pin in the indexing arm, and moved it around until it worked OK. I then drilled the ¼" hole in the vertical support and put in the dowel.

I took a video while I intentionally turned the mechanism slowly and all 6 marbles loaded OK. Per the video, I cranked such that it took 22 sec for the 6 marbles.

6 rev/22 sec x 60 sec/min = 16.4 RPM

100 RPM max, so reduction ratio is 100/16.4 = 6.1 ratio. This is in the worm gear versus spur gear reduction area.

Cranked Too fast on 1st video

Had loading problem. Maybe I can see how fast I was cranking to cause the problem?

I made 11 rev's in 29 sec, so RPM was 11/29 *60 = 23 RPM

On my other earlier test, 24 RPM worked OK, but it did not on this one. 100/24 is about a 4:1 ratio…..probably better to stay down at the 6:1 ratio to prevent jamming.

2nd Beam Height

The height from the base up to the end of the 90 degree elbow discharging from #1 beam is 7.5 inches.

Travel to the 2nd beam is about 8 inches at 6 degree fall.

Fall is 8" * Tan 6 degrees = .85".

elbow into #2 beam has ¼" of fall, so minimum fall is .85 + .25 = 1.10"

Allow some margin, so design height of #2 piston to be 1.25".

So height from base up to bottom of marble hole in piston 2 should be 7.5 inches – 1.25 = 6.25".

Ready to design height of 2nd beam in Sketchup now.

1st Complete Build on January 2, 2024

Everything fit together OK. Had too much friction between 2 pistons and their 2 guide rods.

Ideally, the 2 pistons would fall during their stroke by gravity, if not connected to their links. Used round file on the front piston, it is close to falling by gravity. Could remove top and bottom pieces that guide the 2 rods, clamp them, and drill out both holes to make sure they are closely aligned?

Back piston very tight on the rods. Could drill both guides on that one also.

No Johnson's wax yet on pistons, which will help them lower friction. Maybe water dye the dowels yellow, dry, coat with Johnson's wax and see what a difference it makes to friction.

Front piston fairly light, in terms of moving mass to reduce crank force. Could drill out some holes to remove weight fairly easily.

But boy, back piston has a ton of moving mass!!

Should maybe redesign it to minimize moving mass? Could make from balsa wood that I have.

HOORAY !!

Did the following to reduce friction on both pistons:

-file out ¼” holes in both pistons using round file
-hold bottom and top bearing guides together, run a ¼” drill bit through both of them. Put dowel in 1 hole, while holding in vise, then drill other side

Both dropped by gravity after this. Should get even better with Johnson’s wax lube later.

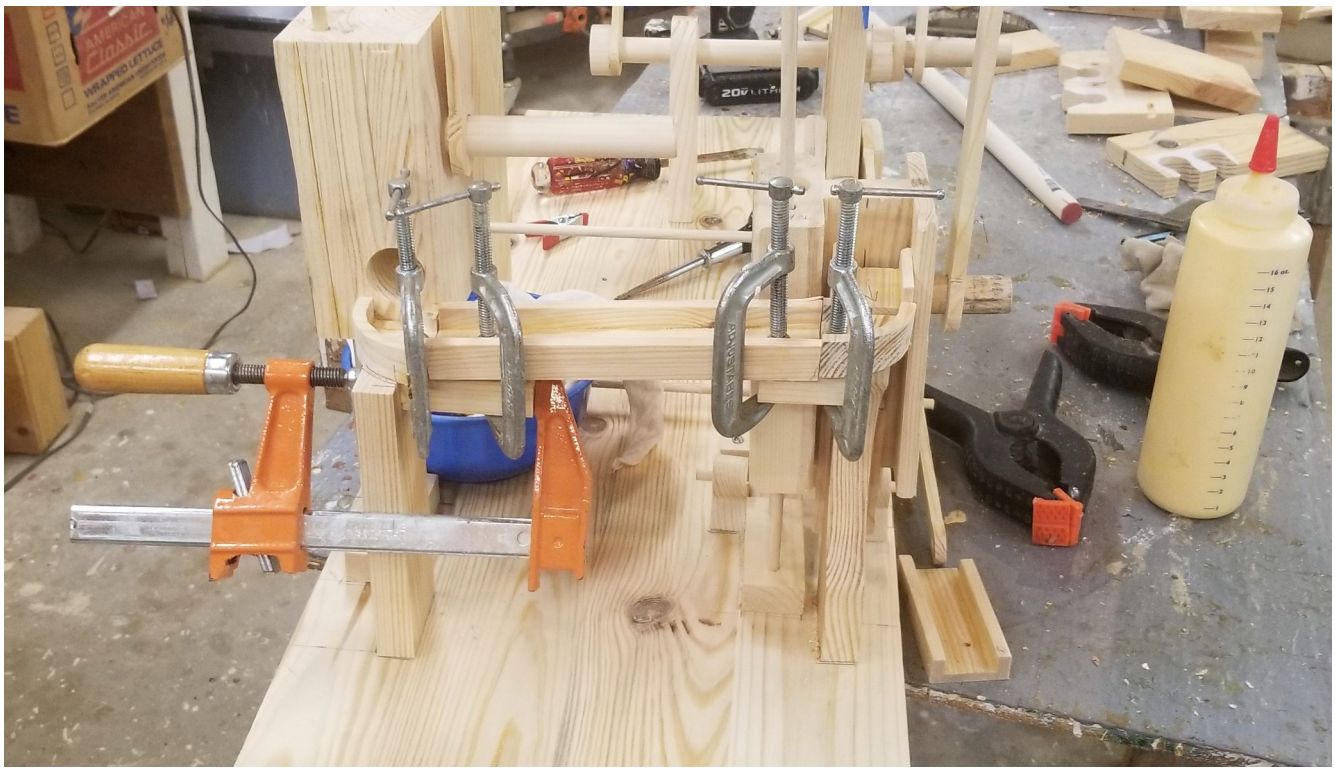
Had to put 1/8” diameter brass pin in front crank to keep it from slipping during testing.

Video

Made video of both pistons working OK for 1st time on 01-03-2024.

on the video, took 19 sec to process 6 marbles…… = 19 RPM

Gluing and Clamping RH Chute



Got Guts of Model Working !!

Had to do some adjustments here and there, including length of LH link on back-set up, but it is basically working now!

An interesting finding was crank speed needs to be low enough such that marbles load OK into the back piston. Too fast, and they do not load correctly.

Timed each rev on the crank from the video, RPM varied from 12 to 15 RPM.

100 max RPM/12 = 8.3 Reduction ratio

Maybe I should go with 8 tooth spur gear on worm gear to be on the safe side?

Time to Make the Worm Gear

I could do the marble return path chutes now, but it would probably be better to make the worm gear first, so I don't interfere with the worm gear mechanism.

Worm Gear Design

The first key input is what the desired speed reduction ratio is, which is the # of teeth on the mating spur gear. I also need to know the spur gear PD (Pitch Diameter). Based upon past models, I will go with a 4" PD. I made up this chart in Excel.

Project	# teeth	PD	Circumference	Distance between teeth	Closest fraction of inch	Speed reduction ratio	Reduction from 100 RPM max
Wood links versus brass Marble lifting device	20	6	18.849	0.94245	7/8	20	
Double Beam Model							
1	20	4	12.566	0.628	10/16	20	5.0
2	6	4	12.566	2.094	2 2/16	6	16.7
4	8	4	12.566	1.571	1 9/16	8	12.5
5	10	4	12.566	1.257	1 4/16	10	10.0
5	12	4	12.566	1.047	1 1/16	12	8.3
6	14	4	12.566	0.898	14/16	14	7.1
7	16	4	12.566	0.785	13/16	16	6.3
8	18	4	12.566	0.698	11/16	18	5.6
9	20	4	12.566	0.628	10/16	20	5.0

Now, the tough decision, what speed reduction ratio do I pick?

To make the model more interesting, the faster it should run…….but it needs to be slow enough the marbles load and unload OK on both beam mechanisms.

Should I double check my 100 RPM max hand cranking speed reference point again?

Right now, I would pick 10 ratio or 10 teeth on spur gear.

Measuring Max Cranking Speed I can do

I don't know where I got the 100 RPM max guideline I have been using.

I was wondering, how can I measure this?? Then I remembered I can video myself cranking at max speed, then play back the video at slow speed and determine start and stop time after quite a few revolutions, then count the number of revolutions I made.

7.25 seconds of crank time
23 revolutions

Max RPM = 23/7.25 x 60 sec/min = 191 RPM !!!!!!!!!!!!

Note: I was turning a solid ¾" dowel on front of the mechanism, not the rotary type handle I use on my models. I might be able to go faster with the rotating handle?

Boy, my 100 RPM max guideline is way off !!!!!!!!!

Where Did 100 RPM Max cranking speed come from?

I searched my digital files, I think I found the original source, from an Excel spreadsheet from Feb 2021, with experimental in file name.

Kissing couple							
1" throw on handle							
Descriptio	# revs	time in sec	RPM	model	2 (inches)		
Normal	50	30	100	Kissing couple	1		
Slow	16	15	64	Kissing couple	1		
so to get 10 rpm on brass marble lifter, and avg RPM of 80, means 8 to 1 speed reduction !!							

NOTE: I described 100 RPM line as a "Normal" speed, not max.

This kissing couple only has a 1” throw on handle, so harder to crank. I must have counted the rev’s I made and used a stopwatch to do this?

Different situation with the rotating handle type crank I now use on my bigger models, that has a 1 7/8” throw.

Maybe I could make a dummy piece, a 1.5” diameter dowel piece with ¾” bore, then run test with that and see if I can crank faster?

Making the Worm Gear Blank

My early worm gears had 3/8” diameter……...and I can use this process on the lathe:

-glue up square red oak blank
-turn round and oversize on the lathe
-drill 3/8” hole from both ends using center drilling fixture
-put on 3/8” steel bolt on lathe and turn to finish size

My later worm gears have a ¾” center bore diameter to fit on ¾” dowels. How did I make those since I don’t have a ¾” threaded steel rod for my lathe?

Might be easiest to just buy a ¾” steel bolt from Ace and hacksaw to about right length?

2nd Video Test to Measure Dale’s max cranking speed

I made a temporary rotating handle from 2” OD dowel, 3 inches long, with 20 mm hole, which served as my rotating handle. From a video of me operating at max cranking speed, I did 32 rev’s in 9.5 sec……..which equates to 202 RPM !!

So non rotating handle speed was 191 RPM, rotating handle was 202 RPM…….so about 6% faster with rotating handle.

So, no wonder my grand-kids can jam up some of my previous models when they invariably try to crank the model as fast as possible !!

Recalculate Worm Gear Ratio

So, I want about 12 RPM on model with max hand crank speed of 200 RPM, so gear reduction ratio is 200/12 = 16.6:1

So, maybe pick 16 to 1 ratio.

So at 200 input RPM, model speed would be 200/16 = 12.5 RPM……..and my earlier studies said it runs OK from 12 to 15 RPM.

16:1 is my final choice.

Worm Gears on Past Models

I measured and typically 4 inches long with a 2” OD.

Worm Gear Blank

So 4 standard ¾” thick oak boards glued up gives 3” square blank, which means turning down about ½” on a side to get final size of 2” OD……...which should be fine.

So make blank 3x3 inches.

1st lather operation is turning from square to round and I need some room on the face plate end, and 1” should be enough……...so blank length = 4 + 1 += 5inches.

Process Will Be

1. Glue up blank that ix 3x3 and 5 inches long
2. Screw to face plate, turn down to round, but larger than 2” final size
3. Using my dowel drilling fixture on drill press, drill ¾” from both ends with Forstner bit, use auger bit if necessary to connect both holes.
   --or saw off LH square end 1” long to get round blank
   -chuck in lathe and drill with ¾” using tail stock, flip end for end and drill
4. Chuck sawed off ¾” steel bolt in lathe, use washer and nut to tighten blank up against chuck.
5. Turn RH side to final 2” size
6. Flip end for end in lathe and turn RH side to 2” final size
7. Blank is completed

Boy, I don’t remember how I made maybe 2 other worm gears with ¾” bores. I may have drilled an 1/8” hole thru the blank and a ¾” wood dowel and put in a temporary brass pin?

Found ¾” Bolt at Fairbury Ace

On my 1939 Montgomery Wards wood lathe, the chuck will accept a steel rod up to 2” long.

The round blank will be 4” long + 2” engagement into chuck = 6” bolt length. Then you need at least another 1” in length for the nut plus 2 washers, so 7” or so.

Longest ¾” bolt Ace has is 8 inches, which should work fine for making any worm gears that are 4 inches long in the future. I just have to hacksaw off the head.

Making the Worm Bear Blank

Starting to rough out the blank on the lathe above using a 3” diameter face plate. I should have put 1 screw in face plate into the blank because it started to rotate on the face plate screw when I about had it roughed out.

After done on the lathe, I cut off the square LH side using my band-saw, then took to the chop saw to make both ends perpendicular to the round blank.

I drilled ¾” hole on the lathe on one end, flipped the piece and drilled from the other way, used a ¾” auger bit to connect the holes and straighten them out.

By the pencil mark on the RH side of the blank, you can see I made it oversize from the 2” final size when I roughed it out.

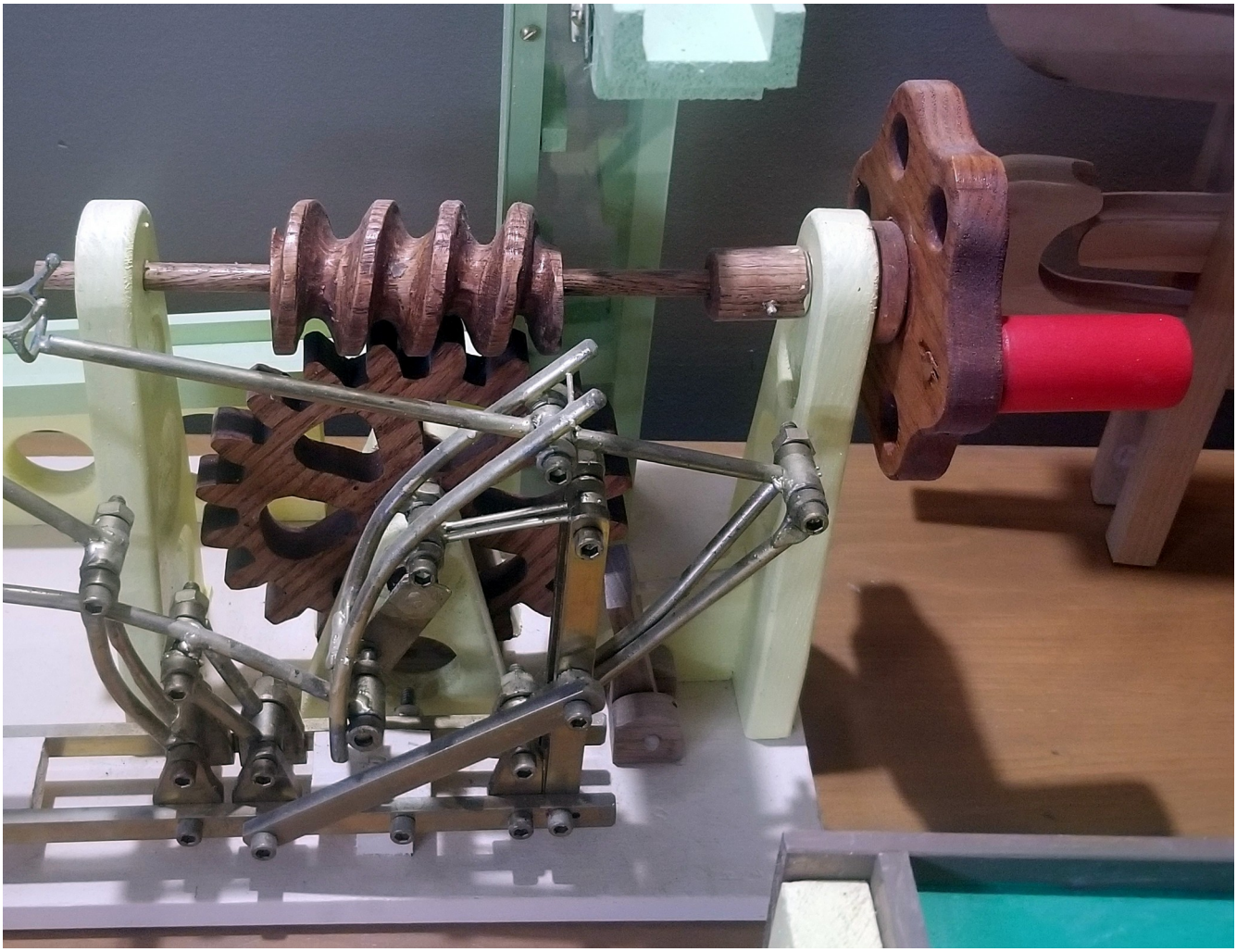
I hack sawed the ¾” bolt off just below the head. About 2” of the bolt will go into my lathe chuck.

Blank is ready to put on the steel bolt on the lathe chuck and turn down to 2” final size.

Which Hand Should Worm Gear be?

I learned the hard way on past projects, it is important to know which hand you want on the worm gear set-up to get the right direction of rotation of the model.

On this older, similar model with respect to the worm gear set-up, if you turn the crank CW as viewed from the RH side of the model, then the mating spur gear turns CCW as viewed from the front.

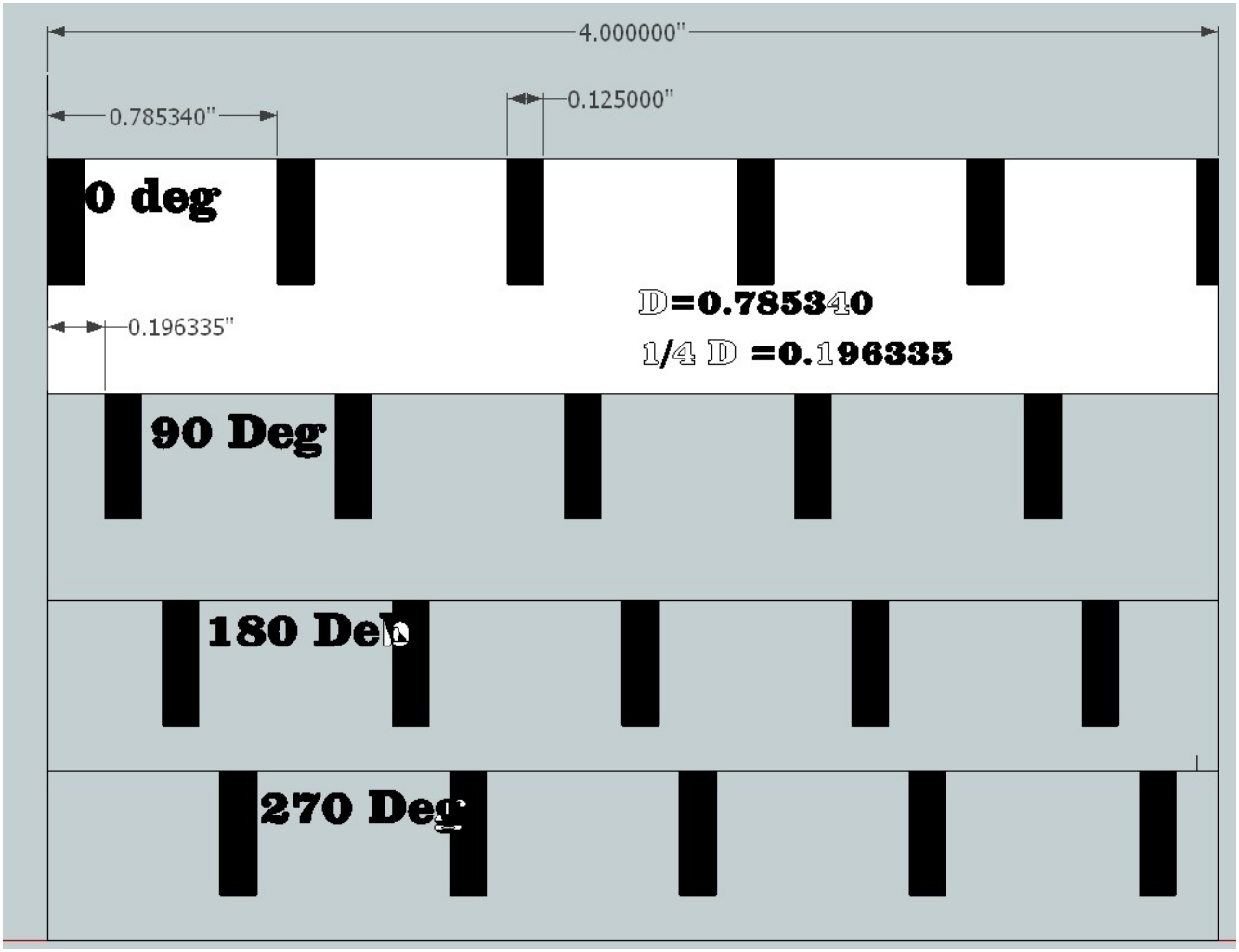


I think I want my spur gear to turn CW since that is the way I have been debugging it. It might work in both directions, I am not sure. I will do the worm gear so it turns CW, then try it out in other direction……...if need be, I can add a ratcheting pawl to prevent the model from being cranked in the wrong direction like I have done on other models.

Worm Gear Paper Template

So with 16 teeth on mating spur gear, the distance between teeth on the worm gear needs to be Pi*D/16 = 0.78534.

To mark the worm gear teeth at 90 degree rotation increments on the worm gear blank, ¼ of this distance as shown below.



Worm Gear Tops of Teeth Marked and Ready to Dremel

I kept track, and it took exactly 1 hour to make the worm gear using only the Dremel with a bit with about a 3/8” diameter. The one hour includes some time on the drill press sanding it, using a 3/8” dowel with a slit sawn in it to hold sandpaper.

I used a short piece of scrap pine with a finishing nail in it, to check took depth and targeted ½” deep for each tooth.

Next is Mating Spur gear with angled teeth

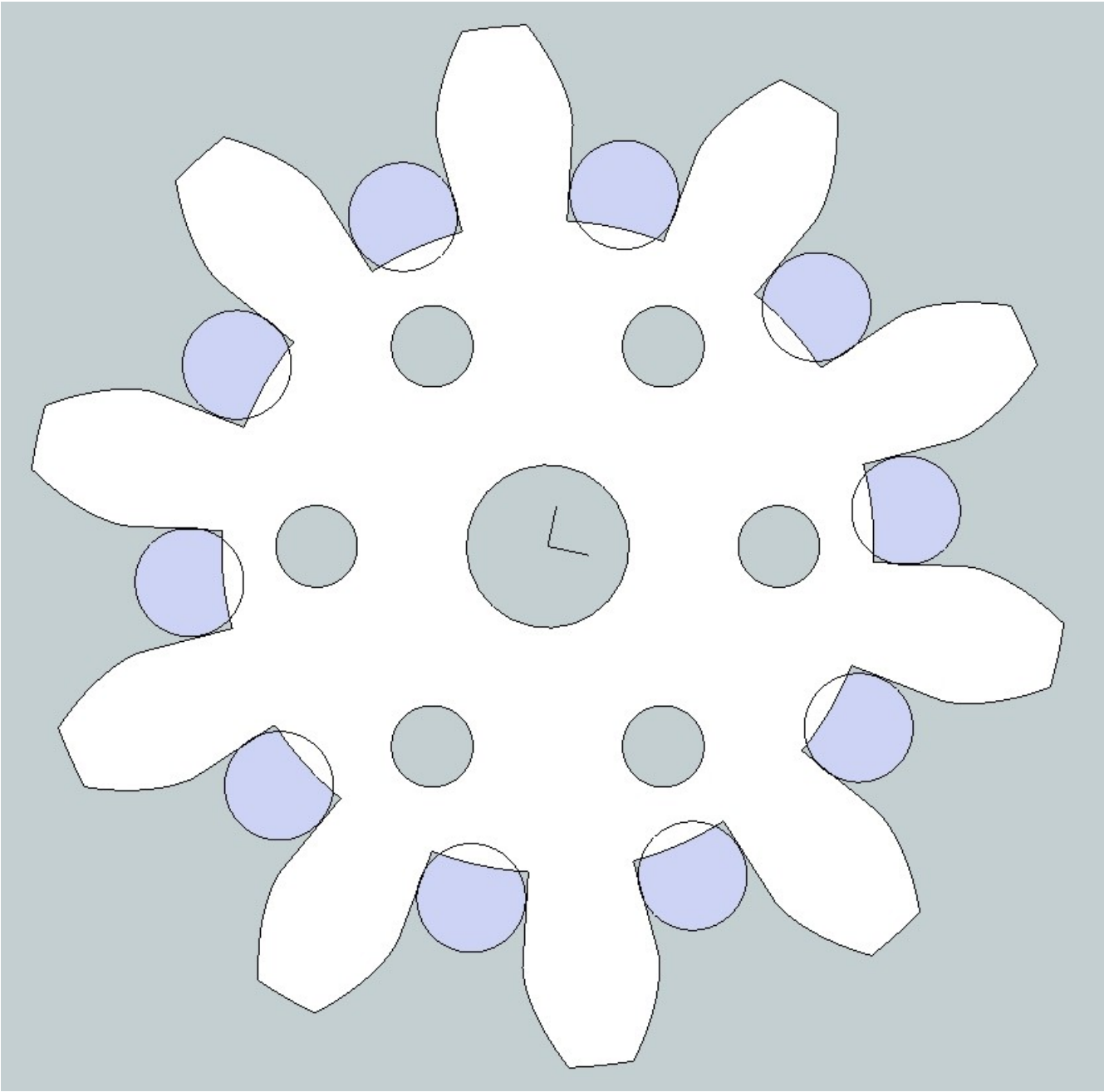
Angle of teeth on the worm gear has a tangent of .5 * (Distance between teeth)/(worm gear dia)

.5 * (.78534)/2

So angle is 11.1 degrees.

I have only made 1 of these tapered spur gears on past projects, see YouTube video I made about how to do it. On that one, I drilled holes for the root of the gears at an angle, then band sawed the teeth.

½” diameter drilled holes seemed to work OK:



OOOPS and DARN

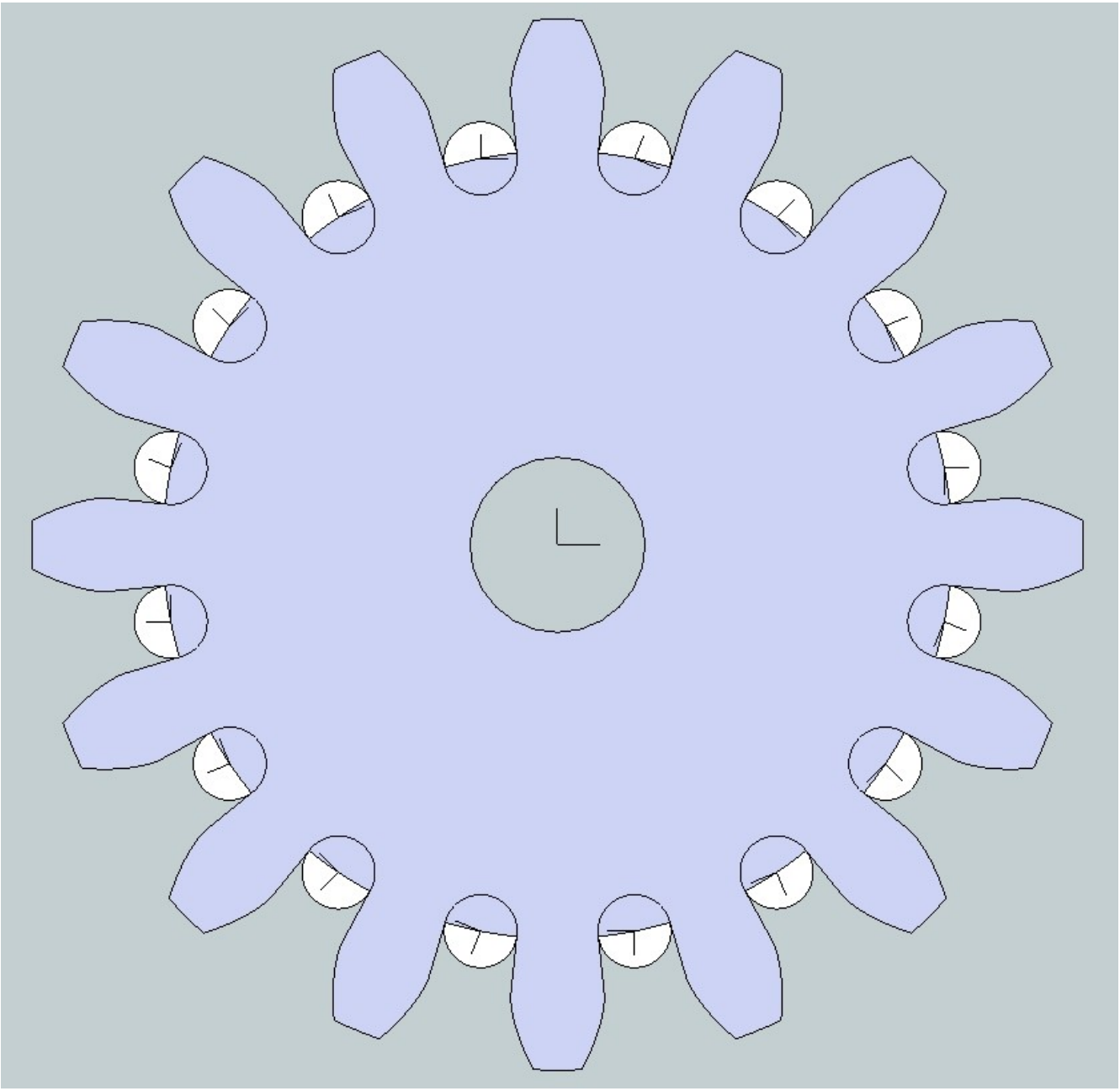
Got angled tooth spur gun done, but did not match my worm gear at all !!!!!!!!!

I messed up!! I had a 10 tooth spur gear in SketchUp, then later changed my mind to use a 16 tooth spur gear……...but I never updated SketchUp to show the 16 tooth gear !!

Oh well, I have made worse mistakes !!

Drawing a 4 PD and 16 Tooth gear

I have a 5/16” Forstner bit, and that is the size that fit best to drill the root of the gear.



Let’s try it again and make the 2nd gear !!

Setting best height for worm gear

In theory, center-line of worm gear would be ½ of 4 PD of spur gear plus ½ of 2” worm gear, which would be 3 inches from center-line of spur gear.

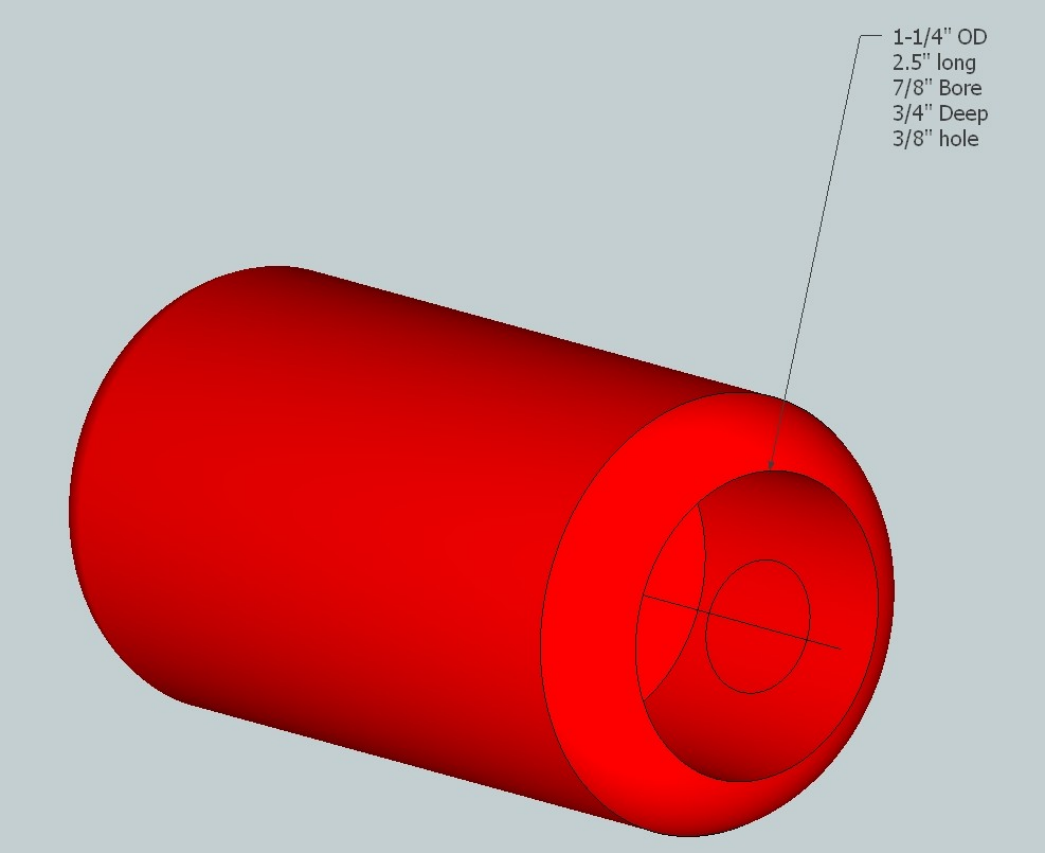
I have learned it is best to test the fit of mating gears, so I made a temporary fixture to check the mating of the gears.

I ended up lowering the center line of the worm gear by 1/8” to get a good mating.

When I installed the vertical pieces with the 1/8” difference, got some interference because I had run-out when I Dremeled the teeth (meaning I did not get them all the exact same depth and width), but I got it to work OK.

Ended up taking all day to make the worm gear, mating spur gear with angled teeth (2 of them because of the mistake), the 2 vertical uprights, the 5 inch diameter cranking wheel. Only thing left is to make the rotating handle on the lathe for the drive system to be completed, except staining.

Steps in making rotating handle:



1. Chop saw 1.25” diameter dowel to 2.5” length
2. Mark centers in each end using my dowel center fixture
3. Chuck in lathe, drill 7/8” with Forstner bit to ¾” depth
4. Flip end for end, drill 3/8” with Forstner bit through
5. Chamfer both ends and sand with 220 grit
6. Put bit I have that is just a hair bigger than 3/8” in portable drill and re-drill to give clearance for 3/8” dowel

Whole Model Works OK without final connecting track

Cranked as fast as I could go, and both pistons loaded and unloaded OK !!!

Now time to finish construction by adding connecting chutes or track.

Will not ring the bicycle bell !!

Tried to come up with a design which uses the most marble momentum on the first major descent track, and it swings ok, but does not have enough force to really ring the bell.

On my old model, the marble really drops much more steeply, then hits a flipper that does a good job ringing the bell.

I may have to give up for now on having a ringing bell on this model.

One problem is that not that much marble momentum, the rotating mass of the swinging arm is critical. I tried to reduce it down to almost nothing, made of wood, but still too much mass.

EUREKA !!!!!!!

I took one of my old bells and tried hanging it such that the marble hits it on the 2nd to last chute, and Voila, got a nice ring !!

January 7, 2025, 5 PM

Model is built. Next steps:

-add some finish attachments (decorative caps on ¾" dowels on main linkage, etc)
-add 90 degree brace between back and front main vertical posts to try to keep them
at 90 degrees from base
-remove material or make pieces more decorative
-paint base
-select color scheme, mix of water dye colors and paint
-re-assemble
-test and make fine adjustments, want error rate no more than 1 in 1,000

Drawing Spur Gear with Angled Teeth that Mates with Worm Gear

I made a Youtube video before about how to draw this in Sketchup.

Twist angle you use has a tangent = ½ * Distance between teeth/worm gear OD

=1/2 *0.78534. / 2

tan = .196335

angle = 11.1 degrees

Cross-Brace betweeen 2 long vertical risers is done

Drawing Worm Gear in Sketchup

I referred back to the Youtube video I previously made on how to draw the worm gear. I drew up both"hand" directions, so I have 2 worm gears. Had no trouble when I said yes in Helix program on direction, but would not work when I said no……..so I put in N instead and presto it worked??

Also did not scale in 1 step, had to use 2 steps, but that is OK.

Ccw or no in direction, is the one I want for this project.

Putting it back together after painting

On about every past model, I have had to make some minor adjustments.

On this one, both pistons did not load correct after painting !!

Figured out root cause of problem !! On 1 of the 2 stands that hold the spur gear, I got it flipped the wrong way, and it resulted in less throw for the rocking beams……..and that is why they did not load right. On next model, I should label pieces better I guess.

End of Day January 9, 2025

Model is back together and running OK now after painting. Hot glued 1/8” brass pins on the drive shafts to keep them from falling out…….yet they are still easily removable if I need to do a repair.

Only thing left is to turn the 10 finials on my lathe. Got 1 test one done today.

Turning 10 of 1.5” Diameter Dowels for Decorative Caps at Rotation Points

BOY: Is this model sensitive !!!!!!!!

Model was working fine in the painted condition, so I started installing the decorative caps at the rotation points.

But, when I got done, the lower mechanism would not dump out the marble at the top of the piston stroke!!

I don't know why this changed?? The only thing I did was to install all the decorative caps. I started on the RH crank end and worked my way left, with the last thing being the moving piston.

Taking a break for a while……..will tackle this last problem after a little break.

Once this problem is solved, only thing left is to retain the 4 dowels, ¼" diameter, on the swinging arm loading mechanism. I think I will use a combination of axle caps on the inside and toothpicks on the outside. I can't reach easily inside, so that is why I might use axle caps on the inside.

Thoughts about solving front loading problem:

If I shorten the LH arm on the front to get the piston to go a tad higher and dump the marble, then it may be too high in the bottom position for marbles to load. I could probably easily raise the load chute a hair by putting a spacer under the vertical mounting board?

Engineering Type Problems Solved on this Project

1. Dimensions for links and balance beam that package into the desired volume.
2. Correct gear reduction ratio
3. Escapement linkage to load marbles

How I fixed front assembly unloading problem

The piston was not going high enough to unload the marble. I felt the rocking arm assembly, and the rocking arm was pretty loose on its ¾" dowel, and if I held it hard against the vertical piece, or no droop, it unloaded ok. I put a short piece of ¾" oak behind the vertical post, pushed it down by hand as hard as I could, then screwed it to the vertical post.

Unloading was still not robust, so I removed the chute connecting the front to the back piston. I carefully bandsawed about 3/16" from the bottom of the front chute post, and then screwed both posts back down. Now I think I have a good unloading assembly that will hold up over time.

So boy, a little slop in the fit of the rocking arm was enough to change it from good loading to bad loading!!

Retaining lower ¼" dowels in moving arm assembly

I ended up using ¼" axle caps on inside and outside. If I had to dis-assemble, I can probably break the axle caps or saw off the dowels next to the caps.

I made a Youtube video of this project.

https://youtu.be/dc4wxO55p9M

Closing Thoughts

This was a fun project with more design challenges than I originally thought!!

Dale C. Maley
January 13, 2025
Fairbury, Illinois